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HOSTS, ADULT EMERGENCE, AND DISTRIBUTION OF THE APPLE MAGGOT (DIPTERA: TEPHRITIDAE) IN UTAH

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Abstract.—The apple maggot, *Rhagoletis pomonella* (Walsh), in Utah was reared from field infested apricot (*Prunus armeniaca* L.), chokecherry (*Prunus virginiana* L.), crabapple (*Malus* spp.), mahaleb (*Prunus mahaleb* L.), pyracantha (*Pyracantha coccinea* Roemer), ornamental hawthorn (*Crataegus monogyna* Jacquin and *C. mollis* Scheele), plum (*Prunus americana* Marshall), river hawthorn (*C. douglasii* Lindley), sweet cherry (*Prunus avium* L.), and tart cherry (*Prunus cerasus* L.) in Utah. Using 1 Mar as a starting date and an 8° C lower threshold, 50% emergence was as early as 1537 degree-days in cherry (both sweet and tart) to as late as 3773 degree-days in pyracantha. The apple maggot has been detected in most areas where river hawthorn grows in Utah, and in all major fruit growing areas, except in Washington and Wayne Counties.

Key Words.—Insecta, *Rhagoletis pomonella,* hosts, distribution, emergence, Utah

The apple maggot (AM), *Rhagoletis pomonella* (Walsh), is indigenous to North America, where its native host is hawthorn, *Crataegus* spp. (Bush 1966). Since it was first reported in 1867 from apple, *Malus* spp. (Walsh 1867), it has been found in other North American hosts: apricot—*Prunus armeniaca* L. (Lienk 1970, Davis & Jones 1986), crabapple—*Malus* spp. (Walsh 1867, O'Kane 1914, Herrick 1920, AliNiazee & Penrose 1981, Westcott 1982, Davis & Jones 1986), pear—*Pyrus* spp. (Prokopy & Bush 1972), plum—*Prunus* spp. (Herrick 1920, Davis & Jones 1986), pyracantha—*Pyracantha coccinea* Roemer (Bush 1966, Davis & Jones 1986), quince—*Cydonia oblonga* Miller (Fisher 1981), rose—*Rosa rugosa* Thunberg (Prokopy & Berlocher 1980), snowberry—*Symphoricarpos* spp. (J. F. Brunner, unpublished data), sour (tart) cherries—*Prunus cerasus* L. (Shervis et al. 1970, Jorgensen et al. 1986, Davis & Jones 1986), and sweet cherries—*Prunus avium* L. (Jorgensen et al. 1986, Davis & Jones 1986).

AM was first collected in Utah from a Malaise trap located about 8 km from the nearest domestic fruit trees in Box Elder County in 1967 (Jorgensen et al. 1986). It was not collected again until 1983 when it was found in Pherocon® AM traps in Utah County during a western cherry fruit fly (*Rhagoletis indifferens* Curran) survey (Edward J. Bianco, personal communication). Since 1983, AM have been collected from many hosts in Utah, especially river hawthorn *Crataegus douglasii* Lindley (Jorgensen 1986, Davis & Jones 1986).

It is thought that the AM was recently introduced into Utah, although it is not clear if it originated from the eastern United States or the Pacific Northwest (McPheron 1990a). McPheron et al. (1988) and McPheron (1990b) have speculated that early populations experienced a "founders effect" in which individuals from tart cherries went through a genetic bottleneck resulting in less genetic

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variation compared to AM from hawthorn (*Crataegus mollis* Scheele) in Illinois and the eastern United States, or from hawthorn (*C. douglasii*) or apple from the Pacific Northwest (McPheron 1990a, McPheron 1990b). McPheron (1990a) found relatively high interpopulation heterogeneity in four Utah AM populations. He suggested that this pattern may be the result of a single introduction of AM into Utah, followed by secondary introductions into other areas of the state. He also reported allele frequency differences at 2 genes in AM populations infesting *C. douglasii* and *P. cerasus* which are similar to allele frequency differences between sympatric apple and hawthorn infesting flies in Washington and genes that mark interhost differentiation in the eastern United States.

AM could cause significant losses to Utah's fruit industry (Bond et al. 1984, Dowell 1990). This research was conducted to gain the information needed to help reduce these losses. Our objectives were to: (1) determine AM hosts that serve as reservoirs for flies infesting commercial fruit, (2) describe adult AM emergence patterns to help time pesticide applications, and (3) determine AM geographic distribution within Utah.

Materials and Methods

AM adults were trapped using Pherocon® AM traps hung within the canopies of suspected host plants, largely Rosaceae. Fruit samples were collected where adults had been trapped and then dissected to detect larvae. Additional fruits were held over trays of moistened vermiculite to collect the larvae as they descended from fruit to pupate. The vermiculite was screened periodically to recover pupae, which were then placed in moistened vermiculite and retained at 4° C for 3–6 months. The pupae were then incubated at 24° C and 16:8 (L:D) until adults emerged. Adults were identified by morphological characteristics (Westcott 1982). Unless stated otherwise, in this paper a host is defined as a field collected fruit in which an AM had oviposited and the resulting larva completed development to the adult.

Trottier et al. (1975), Laing & Heraty (1984), and Jones et al. (1990) have demonstrated that trap catch is a good predictor of AM emergence. Adult emergence (50%) associated with several spatially isolated host plants was determined using Pherocon® AM traps. Captured adults were assumed to have originated from the hosts in which they were trapped as either no other potential hosts were within 0.8 km or all potential hosts in a particular area were monitored. Numbers trapped were recorded 2–3 times per week and traps replaced weekly. We used 1 Mar as a starting date and a lower threshold of 8° C to calculate AM degree-days. Emergence patterns for 1985 were determined from river hawthorn in Provo, and from apricot, cherry (both sweet and tart), chokecherry (*Prunus virginiana* L.), crabapple, mahaleb (*Prunus mahaleb* L.), and ornamental hawthorn (*Crataegus monogyna* Jacquin) in Mapleton. Emergence patterns for 1986 were determined using trapping data from river hawthorn in Provo; cherry (both sweet and tart) and plum (purple and yellow varieties from volunteer rootstock) in Spanish Fork; apricot, chokecherry, crabapple, mahaleb, ornamental hawthorn, and pyracantha in Mapleton. Temperature and moisture data were monitored daily using Omnidata electronic data loggers (Omnidata International, Logan, Utah 84321).

AM geographic distribution throughout the state was determined using Pher-

Table 1. Number of fruit collected, number of pupae, and number of apple maggot adults reared in Utah during 1985.

Host	Location	Date collected	Approx. no. fruit	No. of apple maggot	
				Pupae	Adults
River hawthorn	Mapleton	Jul 31	15,000	2500	522
River hawthorn	Provo	Aug 8	2500	550	331
Crabapple	Mapleton	Aug 14	2500	121	28
Ornamental hawthorn	Provo	Sep 5	2500	56	14
Ornamental hawthorn	Mapleton	Oct 9	3000	51	9
Apricot	Mapleton	Aug 8	750	15	6
Pyracantha	Mapleton	Oct 16	5000	6	3
Mahaleb	Mapleton	Jul 29	2000	27	2
Chokecherry	Mapleton	Aug 14	15,000	1	1
Chokecherry	Spanish Fork	Aug 14	5000	0	0
Plum	Provo	Aug 15	4000	0	0
Plum	Spanish Fork	Aug 15	600	0	0
Apple	Mapleton	Sep 12	300	0	0
Apple	Mapleton	Sep 21	500	0	0
Apple	Mapleton	Oct 9	200	0	0
Apple	Provo	Sep 5	300	0	0
Apple	Provo	Sep 11	500	0	0
Peach	Mapleton	Aug 14	500	0	0

ocon® AM traps to capture adults within the canopies of suspected host plants, especially river hawthorn.

Results and Discussion

Hosts.—Adult AM were trapped in the canopies of 20 potential host species in Utah from 1985 to 1987—apple (*Malus* spp.), apricot (*P. armeniaca*), ash (*Sorbus scopulina* Greene), chokecherry (*P. virginiana*), crabapple (*Malus* spp.), currant (*Ribes* spp.), mahaleb (*P. mahaleb*), ornamental hawthorn (*C. mollis* and *C. monogyna*), peach (*Prunus persica* L.), pear (*Pyrus* spp.), plum (*Prunus americana* Marshall, *P. cerasifera* Ehrhart, and *P. domestica* L.), pyracantha (*P. coccinea*), river hawthorn (*C. douglasii*), rose (*R. rugosa*), serviceberry (*Amelanchier* spp.), sweet cherry (*P. avium*), and tart cherry (*P. cerasus*). They were detected in 97%, 91%, and 92% of the river hawthorn trapping sites monitored by the Utah Department of Agriculture in 1985, 1986, and 1987 respectively (Allred 1988), and adults were reared from >90% of river hawthorn sites from which fruit was collected. In comparison, during 1986, 16%, 16%, and 8% of the trap sites caught AM in apple, sweet cherry, and tart cherry, respectively (Spangler 1986). During 1987, 6%, 13%, and 8% of the trap sites detected apple maggot adults in these same three hosts (Allred 1988). Adults were reared from <20% of cherry (both sweet and tart) sites sampled from 1985–1986. AM were reared from <50% of the crabapple and ornamental hawthorn (*C. monogyna* and *C. mollis*) trees sampled from 1985–1986.

Adult AM were reared from chokecherry and mahaleb which had not been shown to be hosts previously. However, chokecherry may be a rare or incidental host; one adult was reared from approximately 20,000 fruits collected in 1985 (Table 1). Additional verification could not be obtained in 1986 (Table 2) because

Table 2. Number of fruit collected, number of pupae, and number of apple maggot adults reared in Utah during 1986.

Hosts[a]	Location	Date collected	Approx. no. fruit	No. of apple maggot	
				Pupae	Adults
River hawthorn	Alpine	Sep 5	12,500	397	—[a]
Plum (red)	Spanish Fork	Aug 19	1360	34	22
Ornamental hawthorn	Mapleton	Oct 21	7500	65	10
Pyracantha	Mapleton	Oct 14	15,000	7	6
Plum (purple)	Provo	Aug 11	1800	4	3
Mahaleb	Mapleton	Jul 24	7200	22	4
Crabapple	Mapleton	Sep 26	1680	1	1
River hawthorn	Milburn	Oct 10	1500	3	0
River hawthorn	Fairview	Oct 10	1500	3	0
Plum (purple)	Mapleton	Aug 19	300	0	0
Plum (yellow)	Mapleton	Aug 19	1000	0	0
Serviceberry	Mapleton	Jul 16	3600	0	0
Ash	Mapleton	Sep 4	13,700	0	0
Ash	Springville	Sep 20	13,600	0	0
Rose hips	Mapleton	Oct 21	5000	0	0
Rose hips	Mapleton	Oct 23	5000	0	0
Rose hips	Mapleton	Oct 30	5000	0	0
Pear	Mapleton	Aug 21	100	0	0
Pear	Mapleton	Sep 4	80	0	0
Pear	Mapleton	Sep 20	90	0	0
Pear	Mapleton	Oct 3	130	0	0
Pear	Mapleton	Oct 4	100	0	0
Pear	Mapleton	Oct 21	150	0	0
Apple	Spanish Fork	Aug 21	150	0	0
Apple	Mapleton	Sep 20	150	0	0
Apple	Mapleton	Sep 30	150	0	0
Apple	Provo	Sep 30	500	0	0
Currant	Mapleton	Aug 11	2500	0	0

[a] These were retained for future use, but not reared.

most chokecherry lacked fruit. Glasgow (1933) reported mahaleb as a host of two fruit flies closely related to the AM, the black cherry fruit fly (*Rhagoletis fausta* (Östen Sacken)) and the eastern cherry fruit fly (*Rhagoletis cingulata* Loew). He also reported chokecherry as host of the black cherry fruit fly.

AM pupae were not recovered from wild apple or peach; however, apple and peach had been reported earlier as larval hosts (Walsh 1867, Porter 1928). Previous research (Davis & Jones 1986) and inspections by the Utah Department of Agriculture (Spangler 1986, Allred 1988) have not found AM in commercial apples in Utah. However, V. P. Jones (personal communication) reared AM adults that had been collected from non-commercial apples growing near river hawthorn in Wellsville, Utah in 1987.

Varieties of red or purple plum growing from volunteer rootstock (*P. americana*) and ornamental cherry plum (*P. cerasifera*) are hosts of AM in Utah, but yellow plum from volunteer rootstock (*P. americana*) and commercial plum (*P. domestica*) are not (Table 2). AM adults were reared from crabapple, mahaleb, ornamental hawthorn, and pyracantha in 1985 and 1986 (Tables 1 and 2). Pupae were not recovered from serviceberry, ash (*S. scopulina*), pear, or apple (Tables 1 and

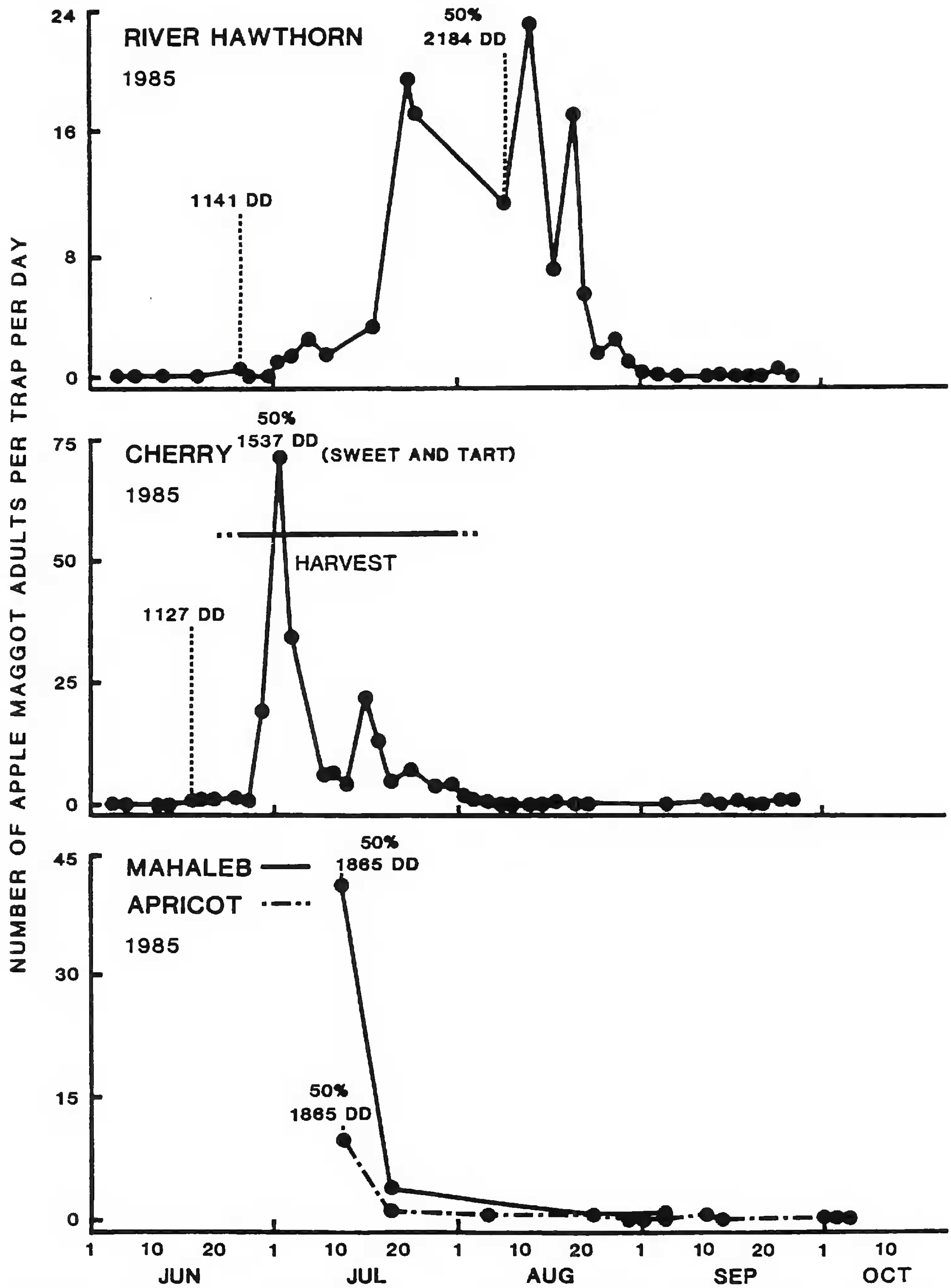

Figure 1. Emergence patterns for apple maggot in Utah from river hawthorn, sweet and tart cherry, mahaleb, and apricot, 1985: first and 50% emergence indicated using degree-days.

2). AM were not reared from rose hips or currant (*Ribes* spp.), although *Rhagoletis ribicola* Doane was reared from currant and *Rhagoletis basiola* (Östen Sacken) from rose hips.

Documented hosts of the AM in Utah now include: apple, apricot, chokecherry,

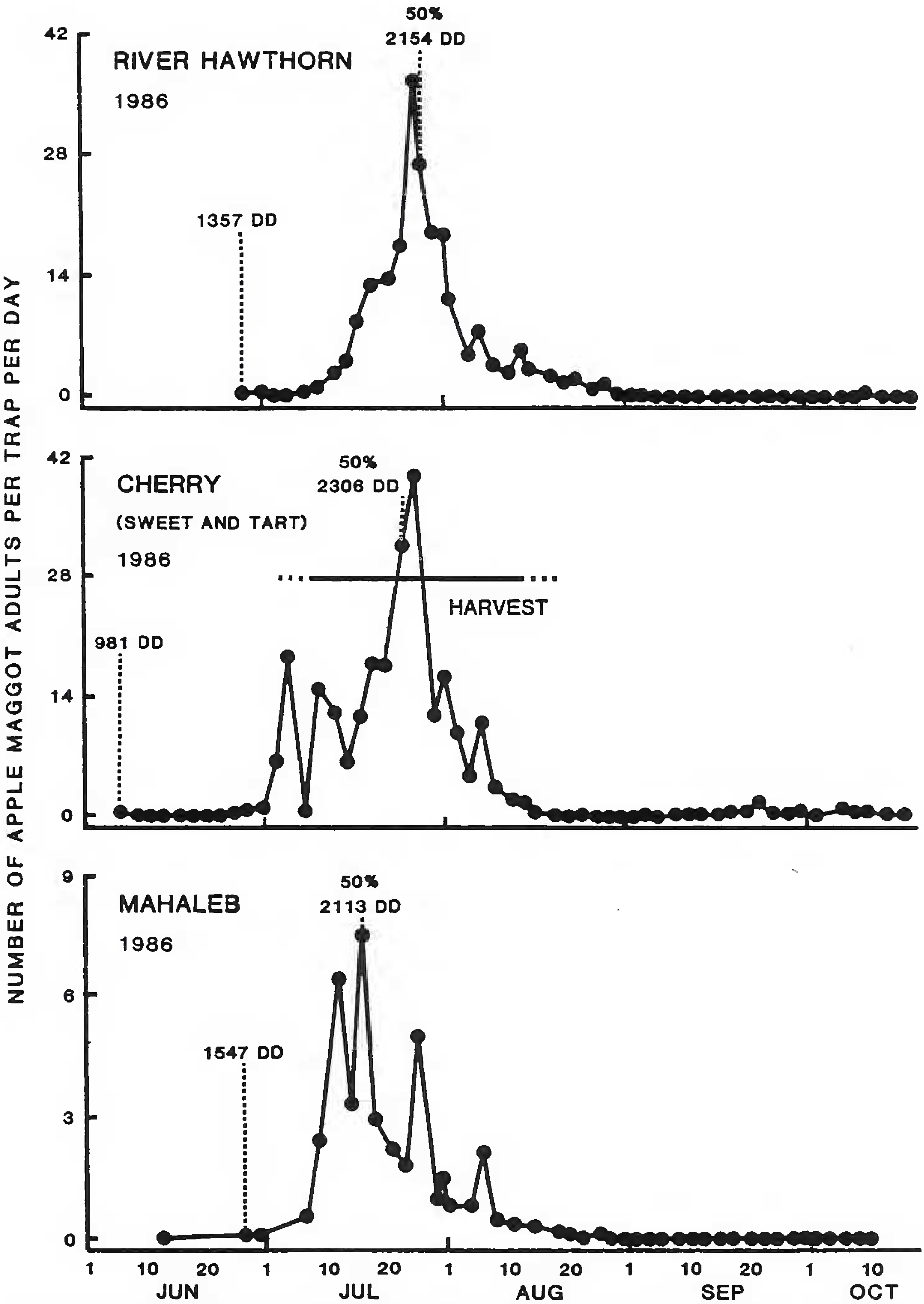

Figure 2. Emergence patterns for apple maggot adults in Utah from river hawthorn, sweet and tart cherry, and mahaleb, 1986: first and 50% emergence indicated using degree-days.

crabapple, mahaleb, ornamental and river hawthorn, plum, pyracantha, and sweet and tart cherry.

Emergence Patterns.—Adult AM emergence is governed by temperature and moisture (Jones et al. 1990, Davis & Jones 1986, Joos et al. 1984). Requirements for chilling and moisture are usually attained during the winter. Survival of fruit infesting *Rhagoletis* species requires synchrony of adult emergence with fruit maturation (Bush 1974). Asynchrony is not unusual when a species is first introduced into a new area. However, to survive, the species must adapt to new hosts or alter its emergence times, as the AM apparently has in Utah.

Data for AM in 1984 (Jorgensen et al. 1986) and 1985 (Fig. 1) indicated that emergence may be synchronized with maturation of fruit varieties from which adults were trapped and 50% emergence times (ET50) of 1537 DD in cherry and 2184 DD in river hawthorn showed that distinct populations may have developed (Fig. 1). Although McPheron et al. (1988) reported that AM may have gone through a genetic bottleneck after their introduction into Utah, their adaptation to a variety of hosts is evident from the data in Tables 1 and 2. The latest ET50s in 1985 were for chokecherry (25 Jul), crabapple (5 Aug), and ornamental hawthorn (1 Oct) (emergence curves not shown). Values ranged from 1537 DD in cherries to 3718 DD in ornamental hawthorn—a difference of 2181 DD in 1985.

Although the emergence patterns in 1986 (Fig. 2) followed much the same trends as observed in 1985 (Fig. 1), the ET50s associated with cherry and hawthorn were not as broad. These reduced ranges were apparently due to the later emergence of adults from early fruits (cherries) in 1986, coupled with earlier emergence of adults trapped from river hawthorn. ET50s ranged from 2113 DD on mahaleb to 3773 DD for pyracantha—a difference of 1660 DD in 1986 (Fig. 2, 3).

Bush (1974), Reissig & Smith (1978), Prokopy et al. (1982), and Diehl (1983) suggested that allochronic isolation, such as that observed between 1985 populations on cherry (both sweet and tart) and river hawthorn (Fig. 1), was important in the evolution of sympatric host races of AM using apple and hawthorn (*Crataegus* spp.) in eastern North America. It is unclear whether the Utah AM populations will follow a similar trend.

The earliest emergence of adult AM detected during 1985 and 1986 in Utah was 6 Jun 1986 (981 DD) in cherry (both sweet and tart) at Spanish Fork (Fig. 2). Early emergence allows infestation of and complete development in both sweet and tart cherries (Jorgensen et al. 1986).

The latest adult trapped during 1985 or 1986 was on 4 Nov 1985, when four inches of snow was on the ground. These late flights were well past the ripening of commercial apple. It is unlikely that larvae, present in the fruit at this late date, could successfully complete development. Dissections of collected adult females, conducted by Utah State University researchers, found immature ovaries. This suggests these flies were either part of a second generation or late emergents from a single generation.

It is not known why AM have not been found in apples from the major fruit growing areas in Utah, particularly since apples and river hawthorn fruits mature at almost the same time. They are less likely to complete development in late maturing hard varieties of apples ('Golden Delicious', 'Red Delicious', 'Rome Beauty'), which are predominantly grown commercially in Utah, than in the early, softer varieties usually grown commercially in the eastern United States ('Yellow Transparent', 'Gravenstein', 'Wealthy', 'McIntosh') (Neilsen 1971, Reissig 1979, Joos et al. 1984, Jorgensen et al. 1986). Jorgensen et al. (1986) reported that the AM in Utah is more likely to oviposit in fruits that mature before the native host (river hawthorn) than after. Accordingly, adaptation to the hard apple varieties

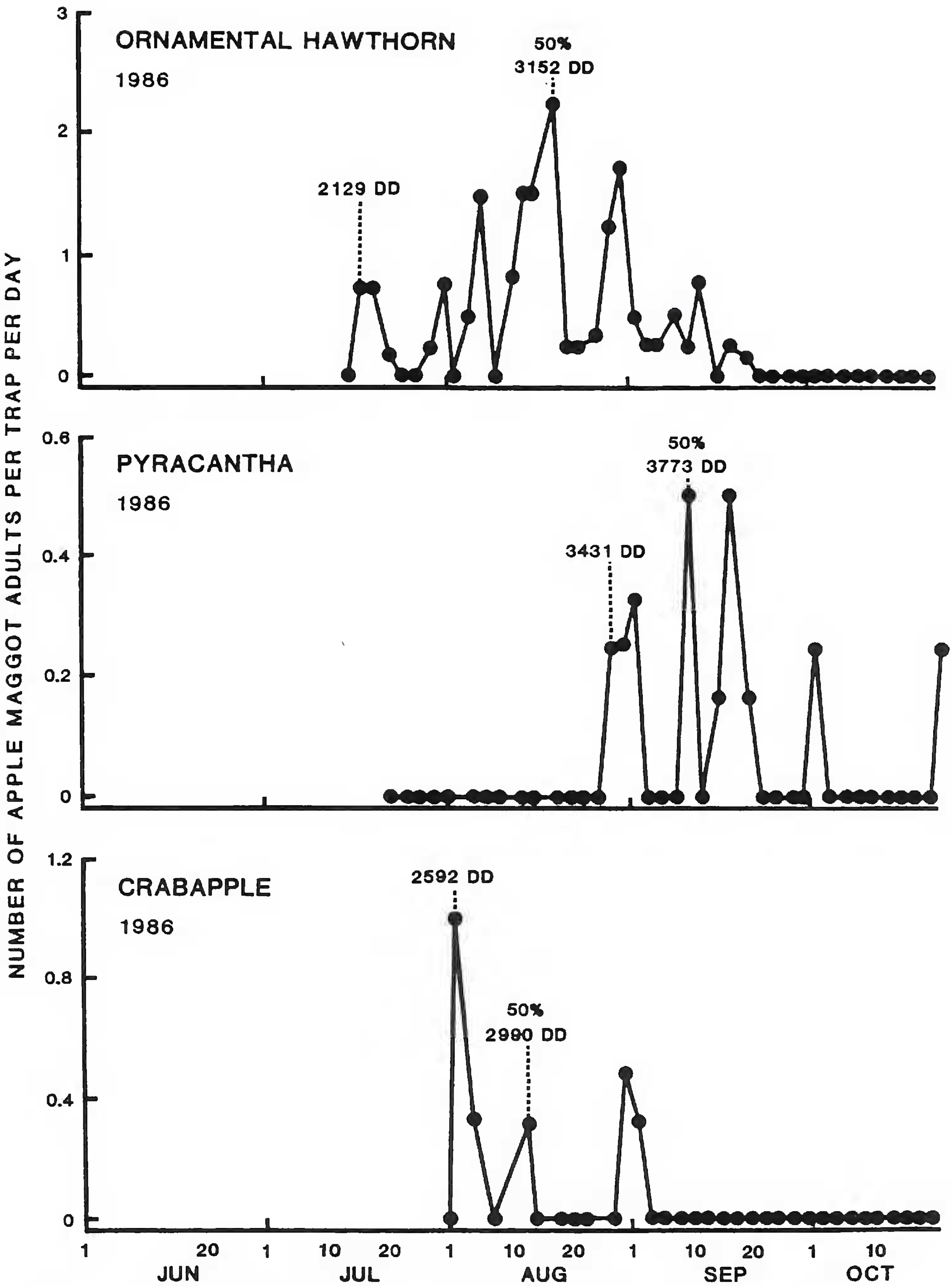

Figure 3. Emergence patterns for apple maggot adults in Utah from ornamental hawthorn, pyracantha, and crabapple, 1986: first and 50% emergence indicated using degree-days.

that mature slightly later than river hawthorn is less likely than adaptation to early-maturing apples and cherries (Jorgensen et al. 1986). Since the AM has apparently adapted phenologically to develop in early rather than late apple varieties, and since the early emergence of Utah AM females is synchronized with

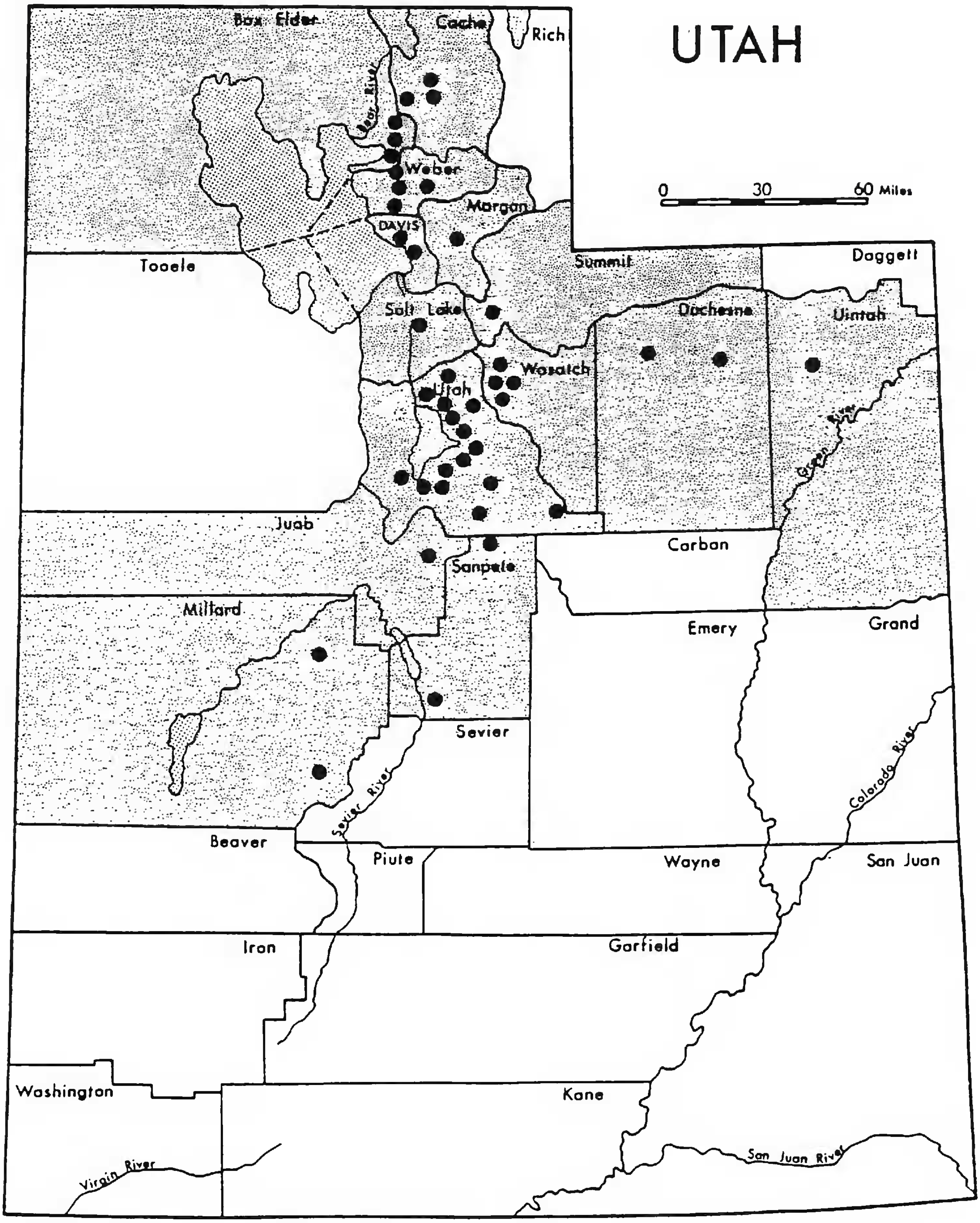

Figure 4. Distribution of the apple maggot in Utah, by county.

cherries, it may take many generations before this insect becomes a general pest of the apple varieties grown commercially in Utah.

Distribution.—Our apple maggot surveys and those by the Utah Department of Agriculture (Spangler 1986, Allred 1988), and Wilford Hansen, Utah State University, found AM in Box Elder, Cache, Davis, Duchesne, Juab, Millard, Morgan, Salt Lake, Sanpete, Summit, Uintah, Utah, Wasatch, and Weber Counties (Fig. 4).

Other counties suspected of having AM, because of the presence of river hawthorn (Welsh et al. 1987), are: Beaver, Daggett, Piute, San Juan, Sevier, Tooele, and Washington. Surveys are needed in these counties in areas where river hawthorn is present near commercial fruit orchards. All major commercial fruit growing areas in Box Elder, Cache, Davis, Salt Lake, Utah, and Weber Counties are threatened with Utah AM eventually adapting to apple.

We conclude that because the AM has been found in apple in California (Joos et al. 1984), Oregon (AliNiazee & Penrose 1981), Utah (V. P. Jones, personal communication), Washington (J. F. Brunner, unpublished data), and in the eastern United States (Pickett 1937, Reissig 1979) and because the AM is found in the majority of the commercial apple growing areas in Utah, it seems probable that this insect will eventually infest unsprayed and commercial apple orchards throughout Utah.

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